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UTILIZATION OF MODIFIED TAMARIND SEED GUM IN MUFFIN FORMULATION AS A FAT SUBSTITUTE

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Abstract
Consumer are demanding low caloric and healthier products. This study examined the efficacy of combine ultrasonic-OSA modified Tamarind seed gum (TSG) as fat substitute in muffins. Modified TSG's stabilizing and emulsifying properties led to its adoption as an oil substitute. The physicochemical characteristics of muffin (proximate, energy value, color, specific volume and texture) were assessed with the substitution of fat at 25, 50 and 75%. A test for acceptability was also carried out. The proximate parameters were ranged between 15.35-17.40% for moisture, 0.59-0.69% for ash, 9.82-10.04% for protein, 0.94-1.11% for fiber, 6.80-15.35% for fat and 57.38-64.19% for NFE. The energy value was decreased from 317.33 to 276.33 Kcal/100g. Then, muffin's crust and crumb color were analyzed, ranged for crust L* value from 52.63 to 60.44 while crust a* and b* value were fall between 8.72-9.04 and 13.51-14.20, respectively. Fat substitution showed no significant effect on muffin's crumb L* and b* value while a* value ranged from 12.50 to 13.40. The muffins containing modified TSG showed lower specific volume as compared to control muffin. After this, texture analysis (hardness, springiness and cohesiveness) was carried out at 0, 7 and 14th day. Hardness, springiness and cohesiveness increased with increasing fat substitution and storage duration. As a result, overall quality score suggested that the muffins with 50% fat substitution were acceptable.

Keywords: Fat Substitute, Muffin, Modified TSG, Energy Value, Texture

1. Introduction

Over the past decade, there has been a noticeable consumer trend towards ready-to-eat foods and a preference for low-calorie and healthy options. However, altering the ingredient quantities to reduce calorie content can have adverse effects on the texture, flavor, appearance and mouthfeel of the product. Simultaneously, with increased awareness among consumers about the importance of reducing fat and cholesterol intake, there is a growing demand for nutritious, flavorful, and high-fiber foods. One potentially effective approach for the food industry to create healthy food without compromising taste is by substituting fat with dietary fiber (Ates and Elmaci, 2017). There is a recognized link between dietary fat consumption and increased risks of cardiovascular disease and several cancer's types such as colon, prostate, breast and ovarian. Consuming saturated fatty acids can elevate blood cholesterol levels, consequently raising the risk of atherosclerosis. Moreover, higher fat intake is closely associated with obesity, diabetes, hypertension and gallbladder disease. Increased

consumption of fat can directly raise the risk of breast cancer by elevating blood estrogen levels and indirectly through its association with obesity. By reducing fat intake in the human diet, there is significant potential to substantially decrease morbidity and mortality rates (Punia and Dhull, 2019).
The application of fat replacer with the objective of lowering the calorie content of baked goods is the most practical strategy (Felisberto *et al*., 2015). Fat mimetics which are carbohydrate based i.e. gums, modified starches, maltodextrin, dextrin, fiber, cellulose and microcrystalline cellulose are utilized. These fat substitutes have a caloric content of up to 4 kcal/g. However, when combined with water it drops to 1–2 kcal/g and in some cases like cellulose, have no caloric content at all. Although the calorie content of the meal is decreased, the primary difficulties faced by the food industry when replacing fats with fat substitutes especially carbohydrate-based, are the inferior quality of food products such as appearance, texture and mouthfeel. As a result, fat alternative is to partially replace fat with fat substitutes, such as carbohydrate-based fat substitutes in baked goods (Ma and Boye, 2013).
The polysaccharide refers greatly to a class hydrophilic as well as some hydrophobic substances that possess high molecular weight that have the capacity to form viscous or gel or viscous solutions in some solvents at low level (Barak *et al.,* 2020; Pirsa and Hafezi, 2023). Polysaccharide especially gums have ability to form gel and strengthen the gas integrity in the cell walls, as an emulsifiers work with starch to limit amylose leaching, affects the starch retrogradation and enhance the air bubble's production and give stabilization effect in the product (Hedayati *et al.,* 2022).
The tamarind (*Tamarindus indica* L.) is a member of the Fabaceae dicotyledon family (Al-Jobouri, 2020). Tamarind seeds are orbicular to rhomboid in shape, firm, flattened, lustrous and reddish to dark brown in color. Fruits contain 320 to 700 g of seeds per kilogram. These seeds are waste product of the fruit's commercial use and an underutilized substance, although there is potential for them to be valuable. The seed is made up of the endosperm (70 to 80 %) and the seed coat (20 to 30 %). The seeds of the tamarind are an abundant source of important amino acids, protein, carbohydrate especially polysaccharide gum and fats (Ghaffaripou *et al*., 2017).
Tamarind kernel powder is a branched carbohydrate polymer chemically defined. The molecular weight of the tamarind seed polysaccharide is 1735 Kilo Dalton (Shao *et al.,* 2019). A 3:2:1 molar ratio monomer mostly composed of the three sugars glucose, galactose and xylose. Xylose and galactoxylose substituents are found on the cellulose-type backbone of polymers. The tamarind seed polysaccharide is a branched polysaccharide with an A-D-1-glucopyranosyl major chain and D-xylopyranosyl lateral chains connected to every 2nd, 3rd and 4th D glucopyranosyl unit via a 1-6 linkage (Shukla *et al*., 2018). It is a nonionic, branched water-soluble polysaccharide having hydrophilic, gel-forming, and mucoadhesive properties (Malviya *et al.,* 2021a). Moreover, it is non-irritating, non-carcinogenic, biocompatible, and compostable. As a promising biopolymer can be utilized in the food, cosmetics and pharmaceutical industries (Malviya *et al.,* 2021b).
Modification is an approach to improve polysaccharide's structural composition, linkage pattern, ionic characteristics and molecular weight (Li *et al.,* 2016). Derivatization of polysaccharide gums make them more suitable for drug delivery as compared to existing synthetic excipients. It can be deravitized using octenyl succinic anhydride (OSA), which introduces hydrophobic properties to the originally hydrophilic structure of native polysaccharides. This modification transforms the polymers into amphiphilic substances with surface-active properties. The incorporation of OSA creates short octenyl succinate lateral chains that position the OSA-polysaccharides at the oil in water (O/W) interface, although the larger chain backbone gives steric stability, preventing droplet flocculation. As a result, OSA-polysaccharides can serve as effective thickeners and emulsifier in O/W emulsions (Chivero *et al.,* 2016). Polysaccharide gums modified with OSA has been utilized as a replacement for number of food ingredients including proteins and lipids. The structural and functional characteristics of polysaccharides are improved by ultrasound, boosting their water solubility, emulsifying properties and heat stability (Kang *et al.,* 2023). While the combined effects of chemical OSA modification and ultrasonic treatment significantly alter the structure and characteristics of polysaccharides and result in high-quality modified polysaccharides (Zhang *et al*., 2020). In this study, it was focused to develop

an alternates that had low-cost such as gums which was modified and used as fat replacer in baked product.

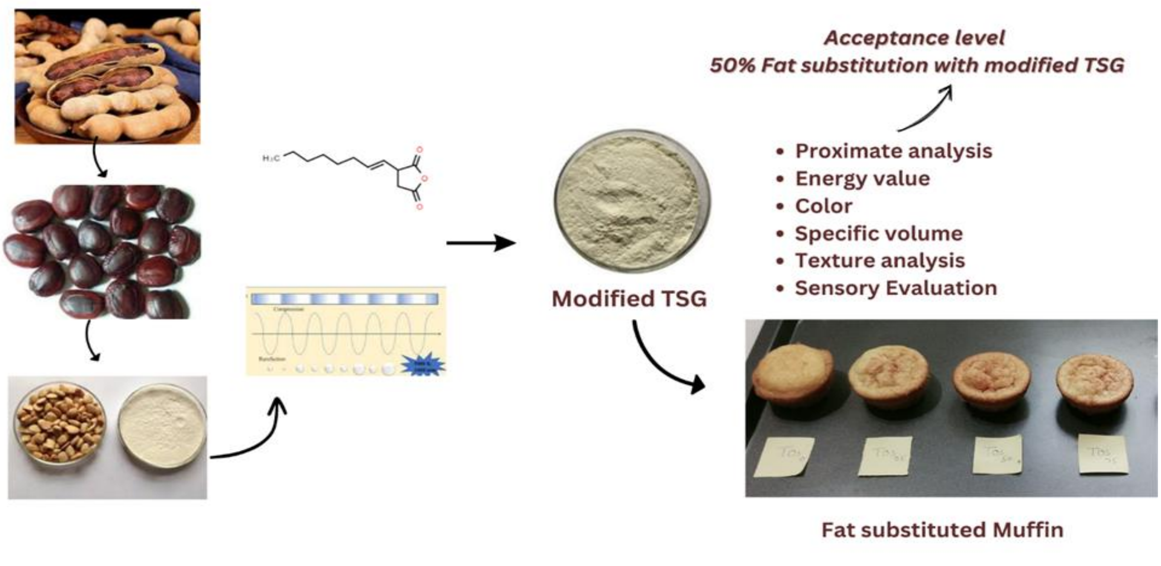
2. Materials and Methods

2.1 Procurement of raw materials

Raw material was procured from the market of Faisalabad, Pakistan. The current investigation was carried out in the laboratories of the Department of Food Science and Technology, GCWUF. The chemicals and standards were procured from Merk (KGaA Merk, Germany) and Sigma Aldrich 2

2.2 Preparation of combined OSA-Ultrasonic Tamarind Seed Gum

The pH of the suspension was adjusted to 8.0 using 1 M NaOH solution after 2 g (dry basis) of Tamarind Seed Gum (TSG) was weighed to prepare a 35% (w/v) gum suspension. The temperature was maintained at 35 °C during alkalization of gum for 20 minutes. The pH was maintained at 8.0 and OSA solution (3.0%, based on dry gum basis) was added. The solution was diluted three times with anhydrous ethanol, v/v. The suspensions were treated for 60 minutes using the ultrasonic processor's probe under the same ultrasonic settings. After 5 minutes of each ultrasonic treatment, the ultrasound was paused for 25 minutes and it was resumed when the stirring temperature reached 35 °C. The total time for Esterification and ultrasonication reaction was 6 hours. After the reaction was completed, 6.5mL of 1 M HCl solution was used to neutralize the suspension's pH to 6.5 before it was vacuum filtered through filter paper. To remove the residual chemicals, the suspension was then rinsed four times, three times with distilled water and once with ethanol solution (95% v/v). After this sample was dried and sieved by using a 100-mesh standard filter (Zhang *et al.*, 2020).



2.3 Muffin preparation

The modified TSG was substituted for oil or eggs (in the control mixture) at amounts of 25, 50 and 75 % respectively. Before making the muffin, a gel was created by combining gum with water and letting it sit for 30 minutes. This gel was then added to the batter. Eggs were manually cracked open, shells were thrown away. All ingredients were weighed individually and then combined well. Table 1 presented a list of all the ingredients used to prepare muffins. A single bowl was utilized for the mixing process. A Kitchen-Aid Professional Mixer was used to combine all the weighed ingredients, premixed them on speed 3 for 60 seconds and then mixing was done on speed 5 for 10 minutes. The batter was measured, poured into six muffin trays (each measuring 120 mm in diameter and 45 mm in height) and baked at 200 °C for 25 minutes. Afterward, cooled for 20 minutes. Then taken out of the pans to chill for a further hour. Muffins were kept in color-coded plastic bags for sensory examination. After cooling, sensory examination was done after 4 hours (Punia *et al*., 2019).

Table 1: Treatment plan for preparation of fat substituted muffins

Ingredients	**Control**	**Oil substitution (%)**		
Ingredients (g or mL /100g)	TC	TOS_{25}	TOS_{50}	TOS_{75}
Cake flour	33.0	33.0	33.0	33.0
Sugar	27.5	27.5	27.5	27.5
Milk	16.5	16.5	16.5	16.5
Egg	13.8	13.8	13.8	13.8
Oil	8.4	6.3	4.2	2.1
Modified TSG (1%)	-	2.1	4.2	6.3
Baking powder	0.8	0.8	0.8	0.8

TC= Control
TOS_{25} = Substitution of oil with gum at 25%
TOS_{50} = Substitution of oil with gum at 50%
TOS_{75} = Substitution of oil with gum at 75%

2.4 Proximate analysis of muffins
The Proximate analysis (moisture content, ash, crude protein, crude fiber, crude fat and Nitrogen Free extract (NFE)) were determined by the standard procedures of AACC (2010).

2.5 Energy value of muffins
Energy value of muffins was calculated using Atwater formula (Karigidi *et al.* 2022).
Energy value = {(Carbohydrate × 4) + (Protein × 4) + (Lipid× 9)}

2.6 Color
An Ultra Scan PRO colorimeter was used to assess the color of muffin following the procedure of Giacomozzi *et al.* (2018). The sample's overall color reflection was calculated using the CIELAB system at observer angle 10°. The variables that were determined a* (negative for greenness and positive for redness), b* (negative for blueness and positive for yellowness) and L* (luminosity: zero for black and hundred for white). Each batch's three samples were evaluated three times.

2.7 Specific volume
The AACC standard method (2010) was followed for measuring muffin volume using millet seeds and the seed displacement method. A digital balance was used to weigh sample. Then specific volume of the samples were calculated by dividing the volume by the weight of the muffins. For the treatments, tests were run in three replications.

2.8 Texture
Each sample crumb's texture profile analysis (TPA) was determined according to the method of AACC (2010) at 0, 7 and 14th days using a Brookfield texture analyzer equipped with a 35 mm diameter tube-shaped aluminium probe and 4500 g load cell. After the crust had been scraped off, the samples were divided in to sections that were 30 mm thick and 30 mm in diameter from the center. Two cycle compression tests with a 12 mm penetration distance (40% strain), 2 mm/s speed was used for the overall test. The force-time figure's parameters were springiness, cohesiveness and hardness, Experiments were carried out in triplicate form.

2.9 Sensory evaluation of muffin

A group of judges (20 to 35 years) conducted the sensory analysis of the prepared muffin in the manner described by Punia *et al.* (2019), with a few minor alterations. A maximum score of 9 was given for each of the categories used in the evaluation of muffin's quality (crust shape, crumb grain size, crumb color, mouthfeel and texture). The aggregate score of these five quality factors was used to determine the overall quality score.

2.10 Statistical analysis

Data was subjected to statistical analysis and means were calculated (Montgomery *et al.,* 2013).

3. Results and discussions

3.1 Proximate analysis

The proximate analysis play an important role to evaluate the quality of product formulated. The mean square are presented in table 5. The obtained results showed highly significant ($p \leq 0.01$) effect on moisture, crude fat, crude fiber and NFE whereas significant and non-significant effect on ash and crude protein content of the muffins. The highest NFE, moisture, crude fiber and ash content were observed in TOS_{75} (64.19, 17.40, 1.1, 0.69% respectively) while lowest values were observed in T_C (57.38, 15.35, 0.94 and 0.59%, respectively). Whereas, highest crude fat content was observed in T_C (15.35%) while TOS_{75} (6.80%) had lowest crude fat content. Every muffin that was supplemented had more moisture than the control group. This is because an ingredient with a greater capacity to absorb water was added, changing the characteristics of the muffin (Zielińska *et al*., 2021). In the muffins, fat was substituted with the modified gum that's why substitution at 75% showed lower crude fat content at all levels than the control samples whereas crude protein content was not significantly varied. The result obtained was in agreement with those reported by Rauf *et al*. (2024) and Arafa and Badr (2023), utilizing chia seed mucilage and taro mucilage in muffin and cake. Similarly, Punia *et al* (2018) determined the proximate composition of the cake containing OSA mungbean starch as fat replacer and El-Sayed *et al*. (2014) of low fat cake using okra and flaxseed gum.

Table 2: Proximate analysis of fat substituted muffins

Treatments	Moisture (%)	Ash (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	NFE (%)
T_C	15.35±0.11^a	0.59±0.02^a	10.04±0.17^a	0.94±0.01^d	15.35±0.92^a	57.38±0.64^d
TOS_{25}	15.89±0.12^b	0.59±0.02^a	9.843±0.14^a	0.99±0.02^c	12.89±0.88^b	59.24±0.58^c
TOS_{50}	16.79±0.14^c	0.66±0.01^b	9.82±0.16^a	1.07±0.01^b	10.10±0.85^c	61.49±0.86^b
TOS_{75}	17.40±0.08^d	0.69±0.01^b	9.82±0.18^a	1.11±0.01^a	6.80±1.01^d	64.19±0.63^a

3.2 Energy value

The energy value is estimated when food is fully burned by measuring the amount of heat emitted. The highest calories were found in T_c (337.17 Kcal/100g) whereas lowest value was found in TOS_{75} (277.33 Kcal/100g). The energy value decrease significantly with the substitution of fat because polysaccharide gum had lowest level of caloric value. Fernandes *et al.* (2021) developed low calorie cake and they found that with the addition of chia seed mucilage, caloric value decreased.

3.3 Color

The muffin's color data was determined in terms of L∗ (lightness), a∗ (greenness) and b∗ (yellowness). The muffin prepared with 100% oil (Tc) consistently manifested the maximum mean values for crust L*, a* and b*color (Table 3). In contrast the muffins made with 75% of oil substitution showed minimum value. The effect of fat substitution in muffins with addition of modified TSG on crumb L* and b* value were non-significant ($p > 0.05$). This implies that the oil substitution with gum did not significantly impacted the crumb color L* and b* values. Current results are in agreement with Fernandes et al (2021) who developed low calorie cake and they found that with the addition of chia seed mucilage, crumb L* and b* value were not altered significantly (Table 4). On the other hand, the fat substitution significantly ($p \leq 0.05$).a* value. The muffin made with 75% of oil substitution with gum (TOS_{75}) consistently showed the maximum mean values for crust a* color whereas muffins prepared with 100% oil (Tc) presented minimum mean values for crumb a* color. The obtained results are in line with the finding of Rauf et al (2024) who developed low fat muffin cake and found that with the addition of chia seed mucilage effect the crust and crumb color.

3.4 Specific volume

The specific volume of the fat substituted muffins presented in Table 4. The muffin prepared with 100% oil (Tc) showed the maximum mean values for specific volume of muffin (2.09 cm^3/g). In contrast the muffins made with 75% of oil substitution with gum TOS_{75} presented minimum mean values for specific volume (2.03cm^3/g). these results are in agreement with Korus *et al*. (2021) and El-Sayed *et al.* (2014) found that specific volume decreased by increasing the amount of waxy corn starch that was modified with sodium octenyl succinate and pre-gelatinization in bread and okra and flaxseed gum in low fat cake.

Table 3: Energy value and crust color analysis of fat substituted muffins

Treatments	Energy value (Kcal/100g)	Crust color		
		L*	a*	b*
T_C	337.17±2.25a	60.44±0.31^a	9.04±0.17^a	14.20±0.20^a
TOS_{25}	317.33±1.52^b	58.29±0.41^b	8.78±0.10^{ab}	13.90±0.20^{ab}
TOS_{50}	297.00±2^c	56.16±0.56^c	8.74±0.10^{ab}	13.83±0.21^{ab}
TOS_{75}	276.33±2.08^d	52.63±0.40^d	8.72±0.09^b	13.51±0.10^b

Table 4: Crumb color and specific volume of fat substituted muffins

Treatments	Crumb color			Specific volume
	L*	a*	b*	
T_C	70.89±1.50^a	0.13±0.04^b	13.4±0.436^a	2.09±0.02^a
TOS_{25}	70.27±0.90^a	0.17±0.02^{ab}	13.30±0.35^a	2.06±0.01^{ab}
TOS_{50}	69.56±1.22^a	0.22±0.02^{ab}	13.00±0.40^a	2.06±0.01^{ab}
TOS_{75}	69.23±0.86^a	0.25±0.03^a	12.50±0.50^a	2.03±0.01^{ab}

3.5 Texture

The texture of baked goods is a crucial factor in determining their quality and contributes to their sensory shelf life. The height of the force peak during the baked product's initial compression cycle indicates its hardness. The moisture, fat content, and aw content are some of the factors that affect the hardness of the baked goods. The composition and recipe of these products also have an impact on these variables (Azmoon *et al*., 2021). The fat substitution with the addition of modified TSG and storage showed highly significant ($p \leq 0.01$) effect on hardness of muffin (Table 5). Whereas interaction of days and treatments for hardness is significant ($p \leq 0.05$). Hardness of muffins increased by increasing oil substitution. This might be explained by the fact that nonfat solids, when used in place of fat, usually cause products to become harder over time. This is due to the fact that fat is a component that keeps cakes softer for longer (Artunduaga and Gutiérrez, 2019). It was found that the storage had a substantial impact on the hardness of cake samples. Throughout the analysis, TOS_{75} muffins consistently had the greatest hardness of all of the treatments. These findings are in line with the results of Fatah-Jahromi *et al.* (2024) who found that reduced water content during the storage in the low fat cake was the primary cause of this rise in hardness.

Springiness quantifies elasticity by measuring the amount of restoration between the first and second compressions (Ataei and Hojjatoleslamy, 2017). The fat substitution with the addition of modified TSG and storage showed highly significant ($p \leq 0.01$) effect on cohesiveness of muffin (Table 6). Whereas, interaction of days and treatments was non-significant ($p > 0.05$). Springiness of muffins increased by increasing oil substitution in the muffins with modified TSG and decreased during storage. Throughout the analysis, TOS_{75} muffins consistently had the greatest springiness of all of the

treatments. Similar result was found by Punia *et al.* (2019) who utilized OSA modified mungbean starch fat replacer in cake.
Cohesiveness is defined as strength of the internal linkages inside a food structure. It depends on how well the structure can withstand deformation (Noorlaila *et al.,* 2017). The fat substitution with the addition of modified TSG and storage showed highly significant ($p \leq 0.01$) effect on cohesiveness of muffin (Table 7). While, interaction of days and treatments for cohesiveness is non-significant ($p > 0.05$). Cohesiveness of muffins increased by increasing oil substitution. TOS_{75} muffins consistently had the greatest cohesiveness of all of the treatments. Fat substituted muffins with addition of modified TSG have a higher degree of cohesion, which can be attributed to their low volume, compressed and compact cellular framework. It was found that sample cohesiveness increased with storage duration. Similarly, El-Sayed et al. (2014) revealed that cohesiveness increased by utilizing flaxseed gum in low fat cake. In contras Fatah-Jahromi *et al.* (2024) who found that cohesiveness decreased with increasing storage in low fat and sugar cake.

Table 5: Hardness of fat substituted muffins

Treatments	**Days**			**Means**
	0	**7**	**14**	
T_C	41.30 ± 0.30^{j}	49.90 ± 0.20^{g}	54.60 ± 0.20^{d}	48.60^{d}
TOS_{25}	41.60 ± 0.20^{j}	51.53 ± 0.20^{f}	55.50 ± 0.30^{c}	49.54^{c}
TOS_{50}	44.36 ± 0.20^{i}	53.23 ± 0.25^{e}	58.43 ± 0.45^{b}	52.01^{b}
TOS_{75}	46.46 ± 0.25^{h}	54.30 ± 0.20^{d}	59.40 ± 0.40^{a}	53.38^{a}
Means	43.43^{c}	52.24^{b}	56.98^{a}	

Table 6: Springiness of fat substituted muffins

Treatments	**Days springiness**			**Means**
	0	**7**	**14**	
T_C	0.88 ± 0.005^{de}	0.81 ± 0.006^{g}	0.79 ± 0.004^{h}	0.83^{d}
TOS_{25}	0.87 ± 0.005^{e}	0.85 ± 0.006^{f}	0.82 ± 0.005^{g}	0.85^{c}
TOS_{50}	0.91 ± 0.003^{c}	0.91 ± 0.004^{c}	0.90 ± 0.002^{cd}	0.90^{b}
TOS_{75}	0.97 ± 0.005^{a}	0.96 ± 0.003^{a}	0.94 ± 0.004^{b}	0.95^{a}
Means	0.91^{a}	0.88^{b}	0.86^{c}	

Table 7: Cohesiveness of fat substituted muffins

Treatments	**Days**			**Means**
	0	**7**	**14**	
T_C	0.66 ± 0.012	0.63 ± 0.011	0.61 ± 0.011	0.63^{d}
TOS_{25}	0.68 ± 0.01	0.66 ± 0.007	0.63 ± 0.010	0.65^{c}
TOS_{50}	0.70 ± 0.010	0.68 ± 0.010	0.65 ± 0.015	0.67^{b}
TOS_{75}	0.74 ± 0.009	0.71 ± 0.010	0.67 ± 0.0015	0.70^{a}
Means	0.69^{a}	0.67^{b}	0.64^{c}	

3.6 Sensory evaluation

For the sensory evaluation, the fat substituted muffins showed a significant difference ($P \leq 0.05$). Figure 1 showed the mean values for each formulation. TOS_{50} was the most preferred formulation overall in terms of crust shape, crumb color, crumb grain size, mouthfeel, texture and overall acceptability. As the amount of modified TSG increased, the trend for the treatments' general acceptability was decreasing. Similar outcomes was reported by the Rauf *et al*. (2024) and Punia *et al*. (2019) who made low fat muffins with chia seed mucilage and low fat cake with OSA modified mungbean starch, stating that the final product was well-liked and approved by customers in general.

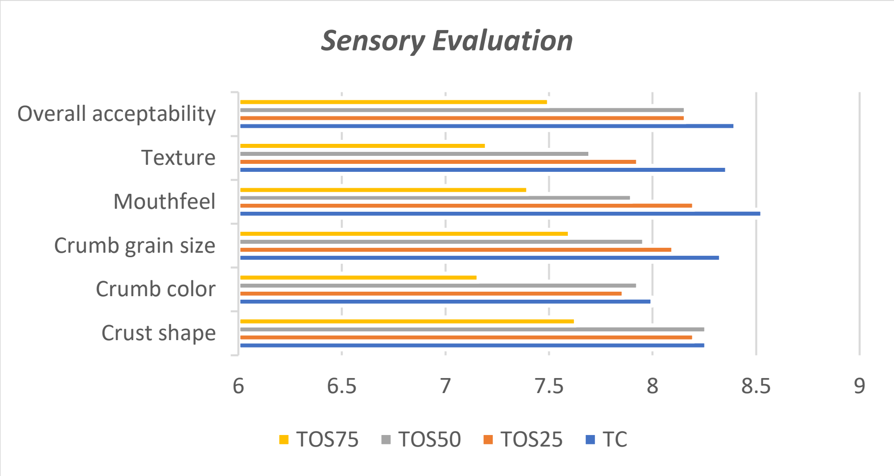


Figure 1: Sensory evaluation of fat substituted muffins

Conclusion

The food industry has become more interested in creating nutritious and low-fat food products. The potential to decrease caloric intake without compromising food taste or texture is present in polysaccharide-based fat substitutes, which also share the same flow characteristics as fat. When utilized as a fat substitute, modified polysaccharides are superior to native polysaccharides. As the amount of modified TSG increased, fat decreased. As a result hardness, springiness and cohesiveness also increased. In order to successfully replace fat in food, the fat replacer must enhance or at the very least retain the food commodity's sensory qualities. In this investigation, 50% Modified TSG gum is recommended as a fat substitute for muffins.

Author's Contribution: Adan Naeem and Rizwana Batool designed the study. Adan Naeem and Saima Tehseen executed the experimental trials and analyzed the samples. Rizwana Batool and Zill-e-huma Nazli analyzed the results. Adan Naeem wrote the original manuscript. All the authors reviewed the manuscript critically and approved the final version.

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